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Synthesis of Vertically Aligned Carbon Nanofiber Films by RF Magnetron Sputtering

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ABSTRACT

The aligned carbon nanofibers were synthesized on Si substrates using RF magnetron sputtering with a hot filament. The hot filament was made of tungsten wire and its temperature was up to 2000°C during the deposition. Nitrogen was used as the sputter gas at a relatively low pressure of $2x10^{-2}$ Torr. The sputtering deposition was carried out at a substrate temperature of 700°C. The nanofibers were grown vertically on the substrates. The diameters and the density of the fibers were about 30-45 nm and 10^9 cm^{-2}, respectively.

INTRODUCTION

Since the carbon nanotube was discovered [1], there have been many reports study on the aligned carbon nanotubes [2-5]. For fundamental research and applications, the alignment of carbon nanotube is important, especially in cold-cathode flat panel displays, vacuum microelectronics, chargeable batteries, and so on [6-8]. In the application of the field emission displays (FEDs), the alignment of the carbon nanotubes is of great important because of the enhancement and uniformity of the field emission [9-11].

In this study, we report a novel method of formation of aligned carbon nanofibers on Ni/Si substrates by RF magnetron sputtering with a hot filament. The carbon nanofibers grew with high density and perpendicularly to the substrates.

EXPERIMENT

The aligned carbon nanofiber films were deposited by a hot-filament-assisted RF magnetron sputtering system, as shown in figure 1. P-doped n-type Si(100) wafers were used as substrates. The substrates were patterned with Ni films by electron beam evaporation. Moreover, the patterned Ni deposited substrates were treated by dipping in a HF solution for 8 minutes, and then annealed at 700°C for one hour.

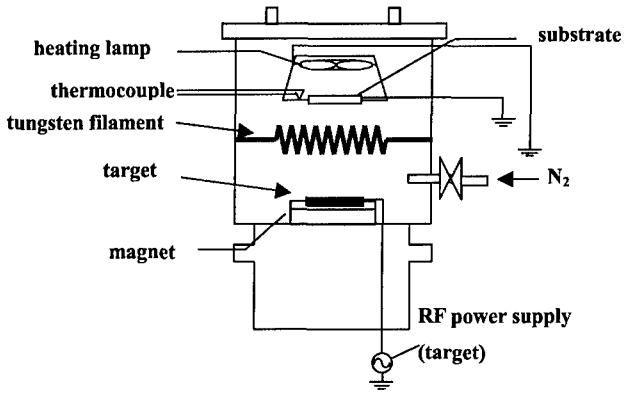

Figure 1. Schematic diagram of RF magnetron sputtering system.

The target was a high-purity graphite (99.999%) with a 50-mm diameter. The base pressure of the chamber was below 5.0×10^{-7} Torr evacuated by a turbo molecular pump. Nitrogen was flowed into the chamber to create a plasma by applying a RF power of 100W at a relatively low pressure of 2.0×10^{-2} Torr. The films were deposited at 700°C for 3 hours. The hot filament, which was made of 99.95% tungsten with 0.3 mm of the diameter, was set between the target and substrate. The distance between the substrate and target was 5 cm, and the distance between the filament and substrate was 3 cm. 6 amperes of filament current was applied and filament temperature was about 2000°C. The characterizations of the carbon nanofiber films were investigated by scanning electron microscope (SEM), and X-ray photoelectron spectroscopy (XPS). The electron field emission property of the film was measured at a pressure about of 10^{-8} Torr. The distance between the cathode (sample) and the anode was 200 μ m. The activation time for the measurement was 60 minutes.

RESULTS

The carbon nanofibers are perpendicular to the Ni/Si substrate surface and are uniform in height. The diameters of the fibers range from 30-45 nm in diameter and about 370 nm in length, respectively. The Ni particle is on the tip of each fiber. The density of the carbon nanofibers is about 8.2×10^{9} cm^{-2}.

From XPS spectrum of the film (figure 2), the peaks of binding energy of C1s is approximately 284.6 eV and N1s is approximately 400eV were observed. There are not any tungsten peaks in the XPS spectrum.

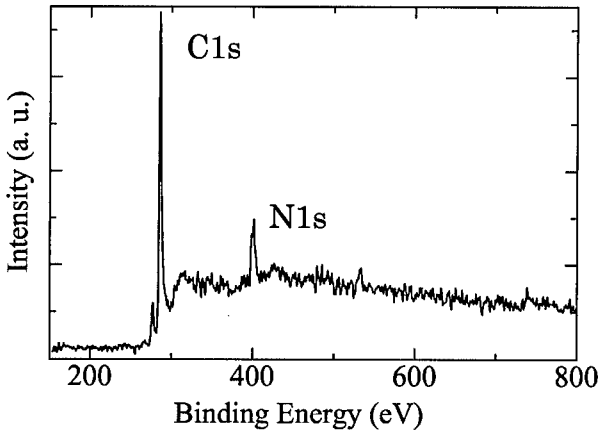

Figure 2. XPS spectrum of the film reveals the peaks of binding energy of C1s and N1s.

The current density-electric field (J-E) characteristic of this a-C film was obtained at a pressure of 5.0×10^{-8} Torr. The J-E plot shows that the electrical field emission current reach as high as 1.0×10^{-4} A/cm^2 at about 15 V/ μ m.

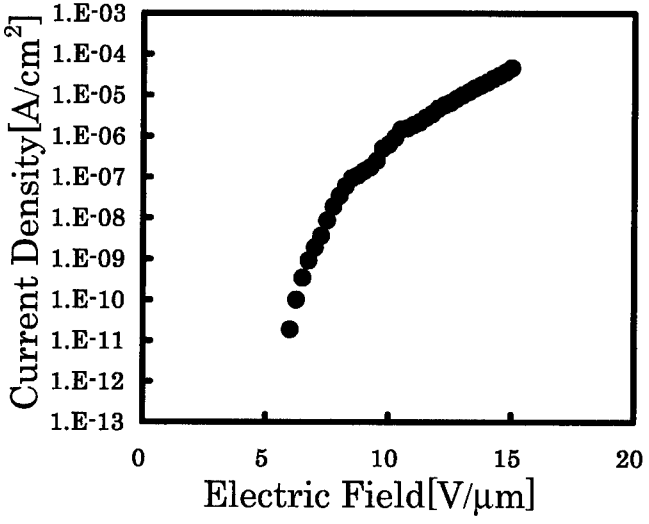

Figure 3. The current density-electric field (J-E) characteristics of this a-C film.

CONCLUSIONS

We have successfully synthesized the well-aligned carbon nanofibers on Ni/Si substrates by RF magnetron sputtering system at temperature of 700°C. The diameter and length of the fiber are about 30-45 nm and 370 nm, respectively. The density of the carbon nanofibers can reach as high as 8.2×10^9 cm^{-2}.

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